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An exact analytical solution for steady seepage from a perched Aquifer to a low-permeable sublayer: Kirkham-Brock's legacy revisited

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Abstract

© 2015. American Geophysical Union. All Rights Reserved. An analytical solution is obtained for steady 2-D potential seepage flow from a nonclogged and nonlined soil channel into a highly permeable porous layer, with phreatic surfaces tapering toward a horizontal interface with a subjacent low-permeable formation. Along this boundary, a vertical component of the Darcian velocity vector equals the formation saturated hydraulic conductivity. The image of the physical flow domain in the hodograph plane is a circular polygon, a triangle or digon in a limiting case of a "phreatic jet" impinging on the low-permeable substratum. The polygon is mapped onto an auxiliary half plane, where the complex physical coordinate and complex potential are reconstructed by the Polubarinova-Kochina method, i.e., by solution of a Riemann BVP. The seepage flow rate from the channel, free surfaces, and a saturated (water-logged) area are found for different thicknesses of the top layer, channel widths, and conductivity ratios of the two strata. In particular, the earlier results of Brock, Kirkham, and Youngs, which are based on a numerical solution, Dupuit-Forchheimer (DF) approximation, and approximate potential model, are confirmed in the full 2-D models. Sufficiently far from the channel, the phreatic surface and interface make a wedge. For a sufficiently deep substratum, three zones are analytically distinguished: an almost vertical 1-D descending flow, an almost wedge-configured 1-D flow, and an essentially 2-D zone in between, where neither a standard infiltration theory nor DF analysis are valid.

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Keywords

conformal mappings, hodograph, infiltration, managed aquifer recharge, perched aquifer, Polubarinova-Kochina method